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THE SCIENTIFIC EDUCATION

OF

MECHANICS AND ARTIZANS.

BY

Prof. ANDREW P. PEABODY,
OF HARVARD COLLEGE.



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THE SCIENTIFIC EDUCATION OF MECHANICS AND ARTISANS.

AN ADDRESS DELIVERED AT THE ANNUAL COMMENCEMENT OF THE WORCESTER (MASSACHUSETTS) FREE INSTITUTE OF INDUSTRIAL SCIENCE, JULY 31, 1872.*

BY PROFESSOR ANDREW P. PEABODY, of HARVARD COLLEGE.

Many years ago there was a strong feeling throughout New England in behalf of manual-labor schools (so-called.) I think I am right in saying that the experiment, wherever tried, failed. The reasons are obvious. The labor was not skilled labor, and therefore gave no mental revenue, and very low wages. It was merely a clumsy endeavor to enable poor young men to pay by the least remunerative kinds of work for their board and tuition at a half-time school. The hand-labor not only taught them nothing, but stupified those of them for whom that work remained to be wrought. Most of them, however, started with not a very large or active brain-capital; for so slow and limping a gait had few attractions for youth of genius or ability.

This institution is at the broadest remove from those, in theory and in practice. Its name so implies. It is an institute of industrial science. Its labor is brain-work; its machine-shop is a recitation-room; its mechanical processes correspond to the collegian's drawings on the black-board; its finished products, to his corrected and approved diagrams. Its object is to train liberally educated mechanics and artisans—men who shall start in life with progressive ideas and the power of rapid self-advancement; who shall diffuse intelligence while they create values; who shall adorn as men the society which they enrich as operatives; who shall have, independently of their callings, a selfhood immeasurably more precious and more honorable.

In addressing the students, graduates, and friends of this institution, I have chosen for my subject the worth of an extended education to mechanics and artisans.

Suffer me to begin with the lowest consideration, that of money's worth—the lowest as it is commonly called, yet by no means to be despised; for though we have the best authority for saying that "the love of money is the root of all evil," this love and the sordid qualities which it implies and engenders are, I think, oftener produced by pinch-

* Furnished by the author for publication by the Smithsonian Institution, at its special request.

ing penury than by earned and merited prosperity; while the position, influence, and capacity of usefulness which money confers are worthy of every man's strong desire and honest endeavor. Especially do they snit the ambition of him who may hope to enrich himself by the creation of values, and not by speculating upon them.

Let us analyze the price of a finished commodity. Here is a lathe, or an air-pump, or a steam-engine, held at a certain price, which, where competition is free, very nearly represents its exact value. That value is composed of three parts: the wages of labor, the wages of skill, and the reimbursement and profit of capital.

The wages of labor, that is, of mere physical force, or of processes which require no knowledge or discretion, constitute the smallest part of this value. Labor can never earn more than a mere subsistence, nor ought it to earn more. Left to itself, it cannot produce more than enough to sustain a meagre, starveling life. The aborigines of North America had dwelt on this soil for hundreds, perhaps thousands of years, yet had not only accumulated no wealth, but were unable, except at rare intervals, to secure a satisfying supply for the rudest wants of nature. A New England farmer, even with the ownership of his land, if he apply no skill or science to his farm, though he, his wife, and his children toil incessantly, can obtain barely the necessaries, hardly any of the comforts of life. Now, the wages of labor must be measured by its products, and by this measure will generally fall short of the cost of comfortable living. They somewhat exceed this standard in our country at the present moment. The reason is that in the development of our resources, the construction of railways, and the opening of fresh soils, the demand for manual labor keeps a little in advance of the supply. But what mere bone and muscle can earn in an old and settled community, what their earnings tend to become and may very soon become here, may be learned by the wretched pittance of English operatives, not sufficient to save their families from a death-rate which shows that poverty is no less destructive than pestilence.

Moreover, low as these wages are, the tendency in a fully-settled country is to a still farther decline. Though production may increase, the demand for unskilled labor diminishes. The time was when all work was done by hand. Now, machinery driven by steam or water-power supersedes the greater part of hand-labor. All the strong men in the habitable world could not exert the amount of physical power which is at this moment at work in the little island of Great Britain. The substitution of machinery for human strength is still going on. Steam is replacing even the shovel and the pickaxe; and the time will come when the Briarean steam-engine, with its fireman and feeder, will everywhere do the work which a hundred arms do now. The supply of labor thus tending constantly to exceed the demand, its wages must sink very nearly to the starvation point.

The second part of the price of a manufactured commodity is the

wages of skill. This is distributed among the workmen employed, in proportion to their respective degrees of skill. He who can work only as a journeyman under the direction of others, or who can perform but a single and not very difficult process in a complicated piece of work, receives a somewhat higher compensation than he would get for carrying a hod or shovelling earth, and this slight advance is the price of the imperfect training and the moderate degree of brain-power which he puts into his work. He, on the other hand, who understands every part of his business, who can knowingly direct the labors of others, who can insure for the articles of his manufacture the highest reputation, and can be relied on for the fulfillment of his contracts, can obtain a price fully proportioned to his superior skill and ability. His income is a compensation for the amount of labor which his skill supercedes. A part of the saving inures, indeed, to the public in the cheapening of the commodities produced, but a large portion becomes the legitimate recompense of his own skill. Competition will prevent his receiving more than he fairly merits. The master-machinist or manufacturer, who has some hundreds of operatives under his employ, even though he have twice or three times the salary of the governor or chief justice of the State, earns all that is paid to him, and is at the same time a public benefactor to a very large extent; for the commodities that he furnishes would, under a less skillful superintendence, be produced at a much greater cost. But for skill like his, clothing and furniture, that are now within every one's reach, would be too expensive for the means of any save the richest purchasers.

But this skill, except in the rarest instances of mechanical genius, is to be acquired by education alone, and not by the mere training of the hand, but equally of the brain. The skilled laborer cannot dispense with the knowledge of chemistry, physics, and mathematics. By chemistry he must learn the properties of materials, their proportions and laws of combination, the action upon them of oxygen and hydrogen, of heat, light, and electricity. By physics he must become acquainted with the mechanical powers, the strength of materials, the effect of friction, the constants and variables which must always be taken into the account to prevent either the deficiency or the waste of force. But physics is a mathematical science, and chemistry has become one; indeed, till it was one, it hardly merited the name of science. Without a very thorough mathematical training, neither chemistry nor physics can be so understood that the artisan can have a fair command of his materials, instruments, and forces; can meet unexpected exigencies; can avail himself understandingly of improved processes; can calculate results, economize resources, and give his products their highest degree of perfection. Then, too, the skilled artisan needs general culture. He is to conduct correspondence, to treat on equal terms with men of intelligence and education, to maintain in society a position worthy of respect and confidence, to do his part toward raising his special calling to

the rank of a liberal profession; for this is what the various departments of mechanical art ought to be, and they will be thus called and recognized, so far as their professors show themselves men of liberal nurture.

The third part of the cost of a commodity, is the reimbursement and profits of the capital expended in buildings, machinery, and raw materials. Capital is, in fact, the accumulated savings of the wages of skill. Labor creates all values. But, as we have seen, mere hand-labor can no more than support the laborer; it leaves no surplus to be saved. Skilled labor, on the other hand, creates more value than the laborer consumes, and the surplus remains in hand—in the ruder states of society, in such wealth as can be locked up in coffers, ward-robes and granaries; in a more advanced community, in such forms as admit of its expenditure in industrial operations. By laws, which I have not time to expound, but as inevitable as those by which the little streams of a valley lose themselves in the river that drains it, small capitals tend to run together, and thus to form the large capitals, which are the object of so much senseless jealousy and hostility. These large capitals are indispensable to the stability of industrial operations; for even in the most lucrative descriptions of business there are not unfrequent seasons of stagnation and reverse, which would be ruinous, were there not capitals ample enough to keep the wheels of industry in motion without immediate revenue.

Capital ought to earn much more than the mere support of its holders and managers. It ought to have such profits as will lead to its own large annual increase, which is needed, in part, to replace the immense amount of property annually destroyed by fire, storm, shipwreck, and disaster, and, in part, to meet the essential outlays for the industrial demands of a population growing rapidly, both in number and in wants. Here let it be remembered that all capital, in order to yield a profit, must be used for industrial purposes. The hoarding of it is a mere fiction. It must all be worked over, and the labor and skill which it employs must be paid for before the capitalist receives the first dollar of his income. It will be observed, also, that large capitals, so far from superseding, utilize, protect, and cherish small capitals, however invested, whether directly in industrial enterprises, or indirectly through banks; and while the absorption of small capitals is constantly going on in a healthy condition of society, their creation is more rapid than their absorption, as in a rainy season the brooks and streams receive from the heavens more water than they can carry into the river.

Now the point which I wish to urge is this: By the education given here, the mechanic or artisan is enabled to secure for himself at once the wages of labor which will feed and clothe him, the wages of superior skill which will yield him a surplus revenue, and the profits of capital, by the investment of his savings year by year, and of the constantly increasing income of those savings. This, indeed, is the proper

way of settling the conflict between labor and capital. Every skilled laborer belongs to both parties, and in fighting against capital he is at war with himself. If he begins life poor, his interest may, indeed, then seem to be on the side of labor; but with every year's savings it is more and more for his interest that capital should yield a remunerative income, and the very measures which, if successful, would impoverish the millionaire, would render his modest surplus earnings unproductive and their investment insecure. The graduates of this institute may regard themselves as capitalists in the near future; for the brain-power that is furnished here is the very material from which wealth is created. Were I familiar with the names in Worcester, I know that I could point out to you not a few of the proprietors of these great manufacturing establishments, who came hither with no resource except hands and brain, and have fairly earned, by industry and skill, every dollar of the tens and hundreds of thousands which it may be literally said they are worth; for, though a man may not be worth all the money he has, he is worth all that he has honestly acquired.

But there are higher grounds on which institutions like this should be cherished. We are training in our schools of industrial science discoverers and inventors in their several departments—men who will shorten and cheapen the labor of production, introduce new applications of science to the useful arts, and add permanently to the wealth of humanity by industrial improvements.

There are some families in the vegetable creation—diceious, so called—in which the fructifying pollen and the fruit-producing blossom are elaborated on different plants. Similar has been the case, for the most part, in the industrial world. Inventions have generally been the joint product of two very different classes of minds, neither of which could have effected anything without the other; and, not unfrequently, between the two an important invention has been kept for many years in abeyance, and, when finally perfected, has been of doubtful or disputed parentage. The germinal idea or principle has been conceived and suggested by a man of learning, science, and studious and reflective habits, but of no practical skill. He has tried in vain to embody it; has encountered, it may be, ridicule, opposition, contempt. Perhaps, after years of fruitless endeavor, he has lapsed into unhonored penury or death. His idea has been taken up by some man who had the skill to actualize what he had not genius or knowledge enough to originate, and he has reaped the honor and the profit of his predecessor's uncompensated study and toil. As by the old slave-law the child follows the fortunes of the mother, so the invention—the brain-child—is, by general consent, accredited, not to the fertilizing mind, but to the producing hand.

An obvious instance may be found in the history of the application of ether as an anæsthetic agent. You know that Drs. Jackson and Morton both claimed the invention, and both, I believe, with equal

truth, though by the law which I have specified the right was Morton's. Jackson conceived the idea, for which Morton's scientific knowledge was inadequate. Morton contrived means for the successful experiment, for which Jackson's practical skill was inadequate. Had Jackson been a practising dentist as well as a chemist, or had Morton been a scientifically educated man as well as a dentist, either might have borne the undisputed honor of discoverer and inventor.

In a certain sense inventions are said to be the work of their age rather than of individuals; but they have generally been a little behind their age. A new and fruitful idea has commonly been current in the scientific world for a generation or more, before it has been actualized, and this for the simple reason that the scientific men have not had the skill requisite for successful experiments, and the men of practical skill have not had science enough to recognize and welcome the dawning of any new light. Thus, an invention of prime importance has often hovered long within the near reach of both speculative and practical men, waiting for that conjunction of science and skill without which it could not assume an available form; and when it has been at length brought forth, many had approached so near it and had so distinctly anticipated it as to claim with entire honesty the merit of its inception.

The history of steam-power affords numerous illustrations of the principle which I have enunciated. A full century of experiments by speculative philosophers on steam as a working force had elapsed—with the construction of various forms of machinery, which demonstrated its potential efficacy, yet were too cumbrous, or too frail, or too restricted in their range of work to be put to any use, except for pumping water from mines—when the steam-engine, with its cylinder and piston separate from the boiler, came from the hands of Newcomen, the blacksmith, and Cawley, the plumber, about the beginning of the last century. Some sixty years later, Watt conceived the idea of a separate condenser, to save the loss of power and the waste of fuel by the alternate heating and cooling of the cylinder—a contrivance which alone and at once placed steam in advance of all other mechanical agencies, and gave sure presage of its enduring and world-wide supremacy. But he, though a mechanical genius of the highest order, was hardly more than a self-taught workman, having had but a single year's apprenticeship to a London mathematical-instrument maker. His conception and foresight of his great invention were clear and vivid; but his own working-power was very limited, and in all Glasgow he could not find artisans capable of the delicate workmanship required, the collective skill of the city not sufficing for the casting and boring of a cylinder, while a hammered cylinder left fatal interstices between its inner surface and the piston. After fourteen years of speculation and experiment he had got no further than to show that he ought to have succeeded, and was yielding to despair under the pressure of poverty and repeated failures, when he entered into partnership with Boulton, a trained and skilled manufac-

turer in iron and steel, in Birmingham, the emporium of skilled labor for the British Empire. Under these new auspices his progress was a continuous triumph—a triumph which, however, was his, only because his partner was a just and true-hearted man; for it is under precisely such circumstances that in numerous instances the actual inventor has succumbed to the skilled and able artisan, while Boulton left to Watt the fame that was his rightful due, and took care that his long years of toil and want should be crowned by an old age of ease and affluence.

Attempts at navigation by steam were made at intervals for a century and a half, or more, but generally by men who had more science than art; often by those who had neither, but only a vague conception of the capacity and destiny of this mighty agent which was to inaugurate a new era for human industry and enterprise. Some of these experiments were partially successful, yet failed to combine the essential conditions of power, speed, manageableness, and durability. Fitch, had he been a well-trained mechanic, would undoubtedly have antedated by several years the establishment of steam-navigation on our western waters. But the glory was reserved for Fulton, who, though not educated as a mechanic, had made himself one by taste, study, and matured practice, and was as familiar with the details of material, method, and workmanship as with the scientific conditions to which all these are subservient. Yet even he was retarded in the successful execution of his plans by the fact that he was not by profession a machinist or a ship-builder. The idea, full grown and available, preceded its final embodiment by at least fourteen years, an interval in which he had experimented in France under disadvantages and discouragements that would have been fatal to the scheme, but for his indomitable elasticity and hopefulness. Had he been master of a machine-shop or a building-yard of his own, he would undoubtedly have launched the Clermont not later than the first year of this century instead of the seventh, and would have been spared the litigations with rival claimants which imbibittered the residue of his life, and hastened its close, leaving, as his biographer says, for "the only patrimony of his children, the load of debt which their parent contracted in those pursuits that ought to command the gratitude, as they do the admiration of mankind."

Of the disabilities under which an inventor may labor in consequence of his not being an artisan by profession, we have a striking illustration in Eli Whitney, the inventor of the cotton-gin. In his case the conception and the execution were united. He was a man of thorough literary and scientific education, and at the same time of a native mechanical genius, which attested itself in his very boyhood by the manufacture of tools, cutlery, and musical instruments, of peculiarly good quality and finish. After graduating at Yale College he went to Georgia under an engagement as a teacher. Cotton was at that time almost worthless as a staple of agriculture and commerce, as it could be cleaned from the seed only by hand, at the rate of a pound of the gross cotton per day

for each laborer. He saw at once the possibility of performing this process by machinery, and constructed a rude and imperfect model, worked by hand, which turned out fifty pounds of the cleansed staple per day. But he found in Georgia neither the workmen nor the materials for perfecting his invention or for multiplying his machines. It took him years to get the manufacture well under way. Meanwhile, in the eagerness for the use of this wealth-yielding process, his patent-rights were ignored; cotton-gins embodying his principle, with trivial variations, were multiplied; the interest of intrusive manufacturers and that of the planters who adopted their contrivances, and thus laid themselves open to legal prosecution, were arrayed against him, and elicited a strong public sentiment to his prejudice; sixty suits were instituted before he obtained a single legal decision in his favor; and his invention, which at once raised the whole southern section of the country from thriftless poverty to abounding opulence, was to him never worth the parchment on which his patent was engrossed.

Now the effect of institutes like yours is to replace the diœcions by monœcions trees—to have the pollen and the fruit-buds grow on the same stalk. You have here, students and graduates, all that careful training can do for you to make you discoverers and inventors—to enable you both to initiate and to actualize industrial improvements, and to reap, without hinderance or rivalry, your merited honor and recompense. Moreover, nothing less than this training can put you on the arena with the promise of success. No accurate practical results can be reached without the most exact calculations; for, whether man know, or be ignorant of, the laws of number and proportion, all substances and forces in nature obey them, and man masters nature only by making them his rule and measure.

Your literary education here tends in the same direction. Especially is this true of the command you acquire of the French language. He who would contribute to the industrial advancement of mankind must know what others have thought and done, how far each separate art and science has advanced, what unsuccessful experiments have been made and therefore need not be repeated, and in what directions men of learning and skill are looking for the new light of which they may unconsciously be the harbingers; and the French has been for more than a century the mother-tongue of science and the useful arts, abounding equally in encyclopedic works and in monographs, and presenting the most advanced views in every department of physical philosophy and of practical technology.

With these exercises of the school-room you have the education of the workshop, far more systematic, comprehensive, and exact than could fall to your lot under the best private auspices. You thus will be prepared to execute or direct your own plans, to embody your new thought in wood, steel, or brass, and to insure for yourselves a fair trial of whatever process or agency may seem to you an improvement on the past.

Think not that the canon of inventive genius is closed. It is but just opening. Agents may be slumbering unrecognized that shall supplant those now in the ascendant. Steam—the sovereign of our time—may yield the sceptre to a mightier energy. The power now obtained by the holocaust of forests and the disemboweling of the solid earth may be replaced by some one of those elementary forces which “spread undivided, operate nuspent.” The general use of condensed air for purposes of locomotion by land and water is now as probable as that of steam was a century ago; and Ericsson has advanced as far in the former as all the predecessors of Fulton had done in the latter. How know we that the electro-magnetic force which we have harnessed to our thought may not one day be yoked to our railway trains? Who can say that the pretended generation of light and heat for common uses by the decomposition of water (the rumor of which, if I mistake not, emanated from this very city,) while an audacious imposture, may not have been an unintended prophecy? Who knows but that the still deficient directing and impelling force may yet be so applied as to give certainty and calculable utility to aerial navigation? Then, too, in many of our established processes, machines, and modes of locomotion there are still limitations, liabilities to accident, possibilities of added speed or efficacy, in fine, a thousand directions in which inventive talent may be fruitfully busy. Nor is there any invention, however insignificant it may seem, which multiplied, as it may be, by thousands or millions, and extending into an indefinite future, may not carry with it an untold saving of cost and labor, and in many cases, even of life. The invention which in the least degree facilitates industry, and increases and cheapens its products, is a benefaction to society which will immeasurably outweigh and outlast the most munificent gifts that wealth can bestow. It is by such charities that many of you, I trust, will do honor to your calling as liberally-educated artisans.

Permit me now briefly to advert to the need which our country has of institutions like yours. Nothing is more evident than the overcrowding, at the present time, of every department of commerce. Up to a certain point commerce is, like the mechanic arts, a creative profession. A commodity is not a finished product till it is brought within easy reach of its consumer, and the merchants—wholesale and retail—who are needed for the successive stages between the producer and the consumer are to that extent co-agents in the production, as are also the bankers and brokers who supply the necessary funds and facilitate the essential pecuniary arrangements. But when members of the mercantile profession are so needlessly multiplied that they create supernumerary stages in the passage of goods from the producer to the consumer, interpose to arrest instead of facilitating their transfer, levy black-mail on every commodity in the market, and get for themselves the lion's share in its ultimate price, they then inflict a grievous wrong on both parties—they make their superfluous profit on the spoils of

both; on the one hand scanting the wages of productive industry, on the other hand cramping the consumers' purchasing power.

That this is the condition of things in our country at the present time, there can be no doubt. The reason, too, is obvious. Our schools educate our young men to a point at which they feel that they sacrifice their self-respect and sink beneath their proper level by becoming mere laborers, or mere routine-mechanics, especially when they are thus placed by the side of, or brought into competition with, the hordes of uneducated and rude immigrants that crowd our labor-market. Those who were themselves content with hand-labor are ambitious of a higher destiny for their sons. Hence the rush into commerce. Hence the scores of applicants for every vacant clerkship. Hence the spectacle—equally ludicrous and sad—of hands that could wield the sledge-hammer, measuring tape, drawing soda-water, and weighing sugar-plums. Everything that can by the broadest construction call itself trade or commerce deems itself respectable; and therefore our towns and cities are supporting twice the number of shopkeepers that they need, and sustaining able-bodied men, too, in paltry commercial industries, which yet would give a competence to our thousands of starving women and girls.

To restore the deranged balance of society, its old honor must be rendered back to labor. Industrial pursuits must be raised in respectability and dignity above the lower walks of commerce, and fully to a level with its higher departments and functions. Both agriculture and handicraft must be made liberal professions. This can be effected only by stocking them with men of liberal culture; for it is not the profession that gives character and standing to the man, but the man to the profession. Our agricultural colleges and our industrial institutes are supplying the needed culture, and are going to replenish the field and the workshop with a new order of large and high-minded operatives, men of liberal tastes, pursuits, and aims, who will do honor to their respective callings, and make them seem worthy the noblest ambition of the aspiring youth of the coming generation. The successful impulse has been already given. It is already no uncommon thing for the graduates of our best colleges to pass at once into the machine-shop or the factory, and to go through the entire novitiate as a raw apprentice might. It has, indeed, been demonstrated, and it will soon be made apparent to the whole world, that there is no department of productive industry in which genius, talent, science, and learning may not find fit investment, ample room to grow, and adequate social position and honor.

There are other points to which I would gladly ask your attention had I not taxed it so long. But I cannot close without reminding the students and graduates of this institute that education has, or ought to have, a higher use than what we call its use. We are too apt to think of the course of early study and discipline, chiefly as a specific preparation for one's business or calling in after-life, as the means of becoming

a good lawyer or physician, merchant, mechanic, or farmer. This, however important, is but a secondary purpose. You might better be, my young friend, a beaver or a sparrow, if skill as an artisan or a fabricator seems to you the great aim and end of life. Over and above your profession, exceeding it, mastering it, should be your selfhood, your manhood, your being as a thinker, a knower, a member of human society, a child of God, an immortal soul. Your course of instruction here has its highest value in giving you real knowledge, materials for thought, stimulants to mental activity, and, withal, food for your moral, spiritual nature. In the laws of the material universe, and especially in the necessary and eternal laws that underlie all mathematical science, you enter into close contact—I would that you might ever know and feel it—with the Infinite mind; you become conversant with forces which are but the multiform, yet undivided, Omnipotence. In the study of physical science you are within temple gates and on holy ground. Let then these pursuits into which you are here initiated for a life-long self-training, vindicate their claim to be regarded as liberal studies by the breadth and depth of thought, sentiment, and character which they inspire and cherish, by the high type of manhood which they foster, by the noble lives to which they give the impulse.

Remember, above all, that your ultimate success depends on character. Genius and skill, unstained by character, will but glitter and vanish. Industry, probity, chastity, sober habits, a quick and healthy conscience, are worth fully as much in the mere material interests of a life of average duration as they are in the judgment of God and in the esteem of good men. Young persons are very apt to discriminate between preparation for this world and preparation for the world to come. To one who has lived as long as I have, the two seem identical. Could I start at your age with the fruits of my three score years of observation and experience, I should take precisely the same route to the surest and highest earthly success, emolument, and honor, which I would take as the nearest way to heaven.



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